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REVIEW ARTICLE

Pulmonary edema: pathophysiology and diagnosis

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SUMMARY

Healthy human lungs are normally the sites of fluid and solute filtration across the pulmonary capillary endothelium. Unlike other organs, the filtrate in the lungs is confined anatomically within adjacent interstitial spaces, through which it moves by a built-in pressure gradient from its site of formation to its site of removal through pulmonary lymphatic channels. The quantity of fluid filtered and its protein content depend on the transvascular hydrostatic and protein osmotic (colloid) pressure differences, and the leakiness of the endothelial barrier to water and protein. Lymphatic drainage can increase several-fold, which means that pulmonary edema—defined as an increase in extravascular water content of the lungs—cannot occur until the rate of fluid filtration exceeds the rate of lymphatic removal. Two main types of pulmonary edema are recognized: first, cardiogenic (or hydrostatic) pulmonary edema from, as the name implies, an elevated pulmonary capillary pressure from left-sided heart failure; second, noncardiogenic (increased permeability) pulmonary edema from injury to the endothelial and (usually) epithelial barriers. Owing to their fundamental differences, each occurs in distinct clinical conditions, requires separate therapy, and has a different prognosis.

KEY WORDS: pulmonary edema; pathophysiology; review

WHEN I WAS A MEDICAL STUDENT, admittedly a long time ago, I was taught, 'the lungs are dry organs.' Like practically everything else I learned in those days, that statement proved to be wrong. Today's medical students discover that fluid and solute are constantly being filtered from the extensive network of pulmonary capillaries within the alveolar walls, and at a rate that equals or exceeds that in many other organs. Moreover, as every practitioner knows, sometimes the factors that normally increase fluid filtration become greatly unbalanced or injury to the lung parenchyma causes excessive leakage and, in either case, pulmonary edema occurs: in other words, once-healthy lungs can become much wetter than they usually are—with disastrous clinical consequences.

The purpose of this essay is first to discuss the physiologic processes that govern fluid and solute filtration and removal in normal human lungs, and then, starting from this physiologic perspective, to show that there are only two basic abnormalities that lead to pulmonary edema, and to highlight the diagnostic differences between these conditions.

FLUID EXCHANGE IN HEALTHY LUNGS

As shown in Figure 1 and discussed in a recent article in this *Journal*,[1,2] there are important morphologic as well as functional differences between the 'thin' and 'thick' segments situated along the air-blood barrier. Gas exchange takes place predominantly through the thin portion (left-hand half of the capillary circumference) where the flat endothelial and overlying alveolar epithelial cell layers adhere tightly to each other with their basement membranes fused into a single layer. By contrast, fluid and solute exchange takes place within the thick portion (right-hand side of the capillary perimeter) where the endothelial and epithelial cell layers are separated from each other by an interstitial space, which is filled with an extracellular matrix containing a few connective tissue fibers.

As discussed in more detail below, it should be noted now that the interstitial space of the interalveolar septum connects directly with the loose areolar interstitial tissue surrounding arterioles, venules and bronchioles in which the terminal branches of the pulmonary lymphatics lie (no lymphatics are located in alveolar walls). The anatomic continuity between the neighboring interstitial tissue spaces provides a pathway for fluid to flow from its site of filtration across the pulmonary capillary endothelium in the interalveolar septum to its site of removal from the lungs through lymphatics surrounding airways and blood vessels. The flow of fluid is ensured by the built-in and normally prevailing pressure difference:[3] the pressure in the interalveolar interstitial space, which is close to alveolar pressure, is always higher than the pressure in the peribronchovascular interstitial space, which is close to pleural pressure.

There is no better way to discuss fluid and solute balance anywhere in the body other than to start

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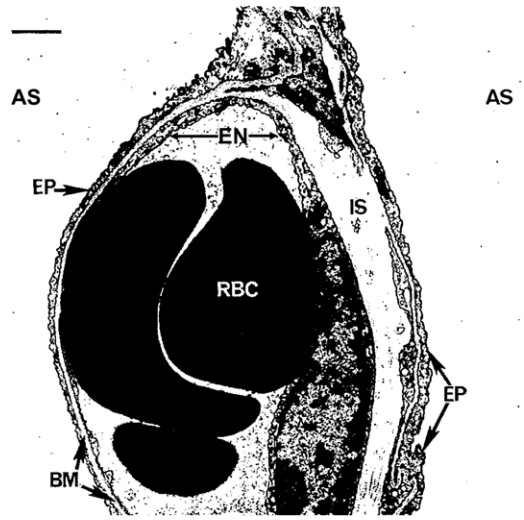

Figure 1 Electron micrograph of a single pulmonary capillary containing red blood cells (RBC) suspended between two alveolar spaces (AS). The 'thin' portion of the air-blood barrier is situated on the left side where the flat extensions of both Type I alveolar epithelial cells (EP) and capillary endothelial cells (EN) lie on a fused basement membrane (BM). The 'thick' portion appears on the other side where the two cell layers are separated by an interstitial space (IS). Horizontal bar = 1 μm (modified from Murray[2] and reprinted with permission).

with Ernest Starling's famous equation describing the factors that govern filtration across a semipermeable (i.e., somewhat leaky) membrane—such as the pulmonary capillary endothelium—which explains both why fluid is continuously being filtered in healthy lungs and what happens in the two basically different types of pulmonary edema:

$$\text{Rate of filtration of fluid} = K_f([P_{cap} - P_{is}] - \sigma\,[\Pi_{cap} - \Pi_{is}])$$

where the coefficient K_f (which includes the hydraulic conductivity and filtration surface area), is essentially a measurement of the permeability of the endothelial barrier to water movement. The variables P_{cap} and P_{is} represent the hydrostatic pressures within the capillary lumen and adjacent interstitial space, respectively; Π_{cap} and Π_{is} designate protein (colloid) osmotic (or oncotic) pressures in the capillary lumen and pericapillary interstitial space, respectively; and the reflection coefficient σ defines the endothelial permeability to protein.

Under customary conditions, filtration of fluid across the pulmonary capillary endothelium is governed by the net balance between the prevailing transcapillary hydrostatic pressure ($P_{cap} - P_{is}$), which causes fluid to flow out of the capillary, and the transcapillary protein osmotic pressure ($\Pi_{cap} - \Pi_{is}$), which acts to retain fluid within the capillary: these four pressures comprise the so-called Starling forces. The actual amount of fluid that forms at any given net force is determined by the permeability of the endothelium to both water (K_f) and protein, σ. (For diagrammatic purposes, we will assume that filtration occurs only across the capillary endothelium, instead of the slightly larger 'microvascular bed'.)

The conditions that usually prevail in healthy lungs are shown schematically in Figure 2 (data modified from Staub[4] and Taylor and Parker[5]). The only one of the Starling forces that is known with precision is Π_{cap}, which is easily measured with an oncometer. P_{cap} must vary along the length of the capillary between its pulmonary arterial and venous ends (the values shown are assumed means); P_{is} is slightly subatmospheric owing to the recoil properties of the layer of surfactant at the air-liquid interface of the alveolar space; and the value for Π_{is} has been inferred from measurements in lymph specimens that drain the lungs. Even with ordinary physiologic variation in the numbers, it is clear that the balance between the prevailing (outward) hydrostatic force, $10 - (-2) = 12$ mmHg, exceeds that of the prevailing (inward) protein osmotic force, $25 - 19 = 6$ mmHg, thus creating a net outward filtration pressure of 6 mmHg. Once formed, the filtrate then flows from the interstitial spaces of the interalveolar septum into the peribronchovascular interstitium, where it enters the terminal lymphatics, which convey the fluid to the hilum and then out of the lungs. The difference between alveolar and pleural pressures, as shown, provides the driving force for the clearance of fluid from the interalveolar interstitial space in which it forms, but another key to the direction and continuity of flow rests in the integrity of the alveolar epithelial membrane, which, owing to its relative impermeability, prevents fluid from entering the adjacent alveolar space: the tight alveolar epithelium serves as an important barrier to fluid movement that preserves gas exchange.

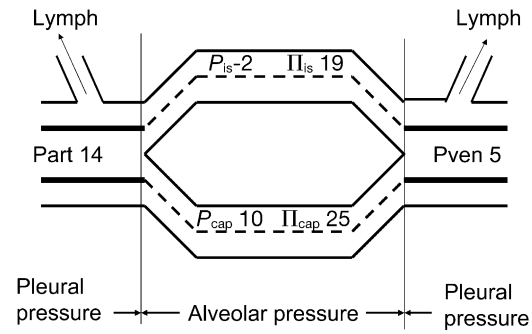

Figure 2 Schematic diagram showing the location and magnitude of the Starling forces in a healthy human lung. As discussed in the text there is a prevailing outward filtration force of 6 mmHg and drainage from lymphatic channels located in the peribronchovascular interstitial spaces. Also shown are the zones affected by pleural pressure and alveolar pressure. P_{art} = mean pulmonary artery pressure; P_{ven} = pulmonary venous pressure; P_{is} = hydrostatic pressure in the pericapillary interstitial space; P_{cap} = mean hydrostatic pressure in the pulmonary capillary lumen; Π_{cap} = protein osmotic pressure in the capillary lumen; Π_{is} = protein osmotic pressure in the interstitial space.

Effect of reducing protein osmotic pressure

Intravascular protein osmotic pressure is largely determined by the serum albumin concentration, which in certain clinical conditions—malnutrition, nephrotic syndrome, protein-losing enteropathy—may decrease to extremely low levels (e.g., 1.0 g/dl). Patients afflicted with any of these disorders, when full-blown, are likely to have anasarca, ascites and bilateral pleural effusions, but they do not have pulmonary edema. As serum albumin and intravascular protein osmotic pressure decrease, fluid filtration presumably increases throughout the body, but the lungs' confining interstitial spaces and lymphatic removal capacity are able to deal with the excess and prevent the development of pulmonary edema. In addition, the protein osmotic pressure in the fluid that is filtered also falls, thereby maintaining a protective pressure difference across the endothelium, albeit a steadily decreasing one. The decreasing transcapillary protein osmotic pressure means that the lungs—although not edematous when pulmonary capillary hydrostatic pressures are within normal limits—will develop pulmonary edema at a lower than usual level of net filtration pressure (see below).

Effect of raising hydrostatic pressure

Both pulmonary arterial and pulmonary wedge (venous) pressures increase during exercise in healthy subjects, especially in the elderly,[6] which elevates pulmonary capillary hydrostatic pressure, sometimes substantially. The resulting increase in transcapillary hydrostatic pressure increases fluid filtration, but the overall effect is mitigated by factors that simultaneously reduce the interstitial protein osmotic pressure level, thus widening the protective transcapillary osmotic pressure.

Because increases in hydrostatic pressure, such as occur during exercise, do not ordinarily affect the permeability of the pulmonary capillary endothelium, the transcapillary movement of albumin remains restricted and the resulting filtrate has a reduced protein osmotic pressure. At the same time, the interstitial tissue matrix that usually restricts entry of albumin, the so-called 'exclusion volume', becomes more porous, which further reduces the concentration of albumin. The protein osmotic pressure in the pericapillary interstitial fluid therefore decreases significantly. Erdmann et al. showed that these two mechanisms combine to widen the transcapillary protein osmotic pressure,[7] a beneficial effect that offsets nearly half of any increase in capillary hydrostatic pressure; in other words, if capillary hydrostatic pressure increases by 10 mmHg, its net effect on fluid filtration is reduced to 5 mmHg, protecting the lungs against becoming waterlogged.

Role of pulmonary lymphatics

Compensatory mechanisms partially mitigate the effects of either a decrease in intravascular protein osmotic pressure or an increase in pulmonary capillary hydrostatic pressure, but in both conditions the filtration rate increases. But lungs are prepared for such exigencies, which, at least in the case of exercise, must be fairly common, with another safety factor that takes over to prevent the development of pulmonary edema: removal of the excess filtrate through the extensive network of pulmonary lymphatic channels. Lymphatics are small contractile vessels whose propulsion of fluid is aided by breathing movements and directed toward the hilum and regional nodes by valves; lymph drainage from each lung flows out of the thorax through vessels in the mediastinum, which empty into the large veins in the base of the neck. These channels can increase their clearance rate several-fold, but only up to a critical value. Pulmonary edema, therefore, does not develop until the rate of fluid filtration in the lungs exceeds the rate of fluid removal through the lymphatics.

PULMONARY EDEMA

Pulmonary edema, defined as an accumulation of extravascular fluid in the lungs, may develop—as the Starling equation indicates—either from an increase in driving pressure for fluid filtration or from a weakening of the barriers that normally restrain fluid and protein movement.[8] First, any one of the Starling forces may change in the direction that favors increased fluid filtration, but clinically significant pulmonary edema is nearly always caused by an increase in pulmonary capillary hydrostatic pressure (P_{cap}) secondary to left-sided heart disease, which explains why this condition is frequently called cardiogenic (or hydrostatic) pulmonary edema. Second, noncardiogenic (or increased permeability) pulmonary edema develops following injuries to the alveolar-capillary barriers in the lung parenchyma, which raise conductivity (Lf) and lower protein restriction (σ). Theoretically, there is a third type of pulmonary edema from lymphatic insufficiency, but this seems to have little clinical importance. For example, after experimental lung excision and reanastomosis, a procedure that severs all lymphatic channels, extravascular lung fluid content increases, but only slightly and transiently.

Cardiogenic pulmonary edema

The regular and sometimes marked elevation in pulmonary capillary hydrostatic pressure that accompanies various disorders of the left side of the heart—coronary artery disease, myocardopathies, aortic or mitral valve abnormalities—like the lesser effect of exercise, does not affect barrier permeability, which means that the safety factors described earlier, protein sieving and increased albumin distribution, operate to lower the interstitial protein osmotic pressure value and offset roughly half the rise in capillary hydrostatic pressure. As shown in Figure 3, an increase

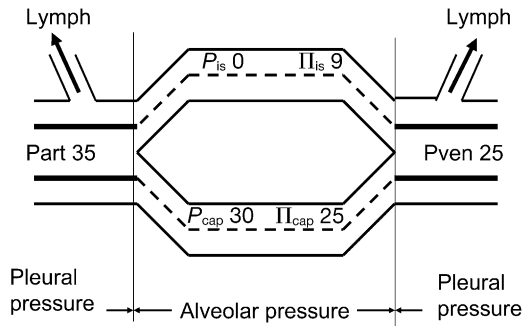

Figure 3 Schematic diagram showing the Starling forces in a patient with cardiogenic pulmonary edema secondary to left ventricular failure with an increase in P_{ven} to 25 mmHg. Also shown are the increased protective protein osmotic pressure difference, increased P_{is} and increased lymph flow. Abbreviations as defined in Figure 2.

of 20 mmHg in pulmonary capillary hydrostatic pressure to 30 mmHg, secondary to an elevation of left atrial-pulmonary venous pressure to 25 mmHg, is associated with both a decrease of 10 mmHg in interstitial protein osmotic pressure to 9 mmHg and an increase in lymph flow. The figure also shows that interstitial hydrostatic pressure is no longer slightly below zero, because the interstitial space is engorged, which raises its pressure slightly and offsets by the same amount the increased capillary hydrostatic pressure.[9]

At first, the excess filtrate seeks and fills the peribronchovascular interstitial spaces, which (depending on lung size) can accommodate 300–400 ml of fluid, forming the 'cuffs' that are often visible on chest X-rays; distended lymphatics, Kerley B lines, are another radiographic feature of cardiogenic pulmonary edema. Once the interstitial spaces are brimming, fluid begins to flood the alveolar spaces. Neither the mechanism nor the pathway for alveolar flooding is certain, but it is an all-or-none phenomenon: suddenly, scattered alveoli in the dependent lung regions are completely drowned with fluid while their neighbors remain air-filled; with ongoing excess filtration, they, too, will flood.

Noncardiogenic pulmonary edema

As already indicated, noncardiogenic pulmonary edema results from injury to the lungs sufficient to increase endothelial permeability and cause extravasation of protein-rich fluid into the interstitial and alveolar spaces. The Starling forces become altered as a sequel to the excess leakage, but they are not responsible for it. Moreover, the usual clinical causes of noncardiogenic pulmonary edema have nothing to do with heart disease, although they may occasionally complicate it; all these conditions, when severe, create what is known as the acute respiratory distress syndrome, which has been subdivided into two categories of lung injury, direct (e.g., inhalation of corrosive gases and gastric aspiration) and indirect (e.g., sepsis syndrome and pancreatitis).[10]

In theory, the sequence of edema accumulation in noncardiogenic pulmonary edema, first into the interstitial spaces and then into the alveolar spaces, with an increase in lymph drainage throughout, should be the same as in cardiogenic pulmonary edema; in reality, because the alveolar epithelium is often damaged by the same process that increases permeability of the vascular endothelium, alveolar flooding is a frequent and early accompaniment of diffuse lung injury, whatever its cause.

The schematic diagram in Figure 4 illustrates many of the key physiologic features of noncardiogenic pulmonary edema. Primary among these—because a severe increase in permeability allows virtually pure plasma to flow across the damaged endothelium—is that interstitial protein osmotic pressure becomes identical to intravascular protein osmotic pressure ($\Pi_{cap} = \Pi_{is}$), thus eliminating the usually protective transvascular osmotic pressure difference. Similarly, when the alveolar epithelium is also damaged and its permeability is increased, pure plasma floods the alveolar spaces, as documented by finding equal protein concentrations in specimens of edema fluid and plasma.[11] Note also that interstitial hydrostatic pressure is increased from engorgement of the interstitial space, as in cardiogenic edema, and that lymph flow is elevated.

Figure 5 is a composite diagram that illustrates the essential points of the preceding descriptions.[12] In cardiogenic pulmonary edema, when protein osmotic pressure and endothelial permeability are normal, safety factors prevent the formation of pulmonary edema during left atrial pressure elevations of up to about 20–25 mmHg. Above this threshold, edema fluid (depicted as extravascular water, the variable that is usually measured experimentally) begins to accumulate in progressively increasing amounts. The

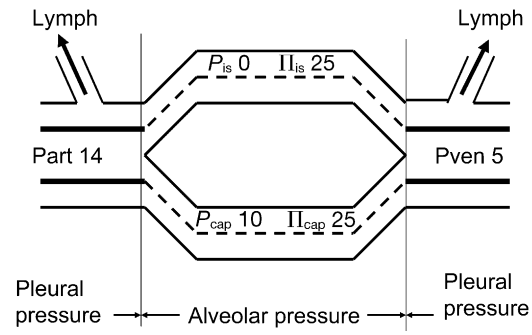

Figure 4 Schematic diagram showing the Starling forces in a patient with cardiogenic pulmonary edema caused by increased permeability of the pulmonary capillary endothelium allowing pure plasma to enter the pericapillary interstitial space and eliminate the usual protein osmotic pressure difference. Also shown are the increased P_{is} and increased lymph flow. Abbreviations as defined in Figure 2.

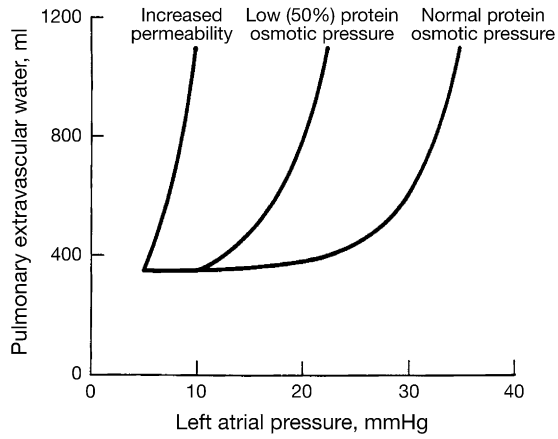

Figure 5 Relationship between pulmonary extravascular water content and left atrial pressure. Right hand curve represents conditions of normal capillary permeability and plasma protein osmotic pressure; middle curve represents normal permeability and protein osmotic pressure 50% normal; left hand curve represents marked increase in barrier permeability regardless of protein osmotic pressure (reprinted from Hopewell and Murray[12] by permission).

figure also shows the effect of a reduction in protein osmotic pressure from a decrease in serum albumin concentration: pulmonary edema is not present at ordinary left atrial pressures, 5–10 mmHg, but develops at considerably lower hydrostatic pressures than when protein osmotic pressure is normal.[13] Conversely, in noncardiogenic pulmonary edema, when endothelial permeability is markedly increased, fluid leaks into the lungs at normal left atrial pressures.

Other causes of pulmonary edema

Overperfusion pulmonary edema from excessive infusions of blood, blood products and fluids is included among cardiogenic types of edema, because it, too, is caused by increased hydrostatic pressure;[9] conversely, post-lung transplantation and reexpansion pulmonary edemas, both ischemia-reperfusion-mediated injuries,[14] easily fit within the noncardiogenic category. But high-altitude and neurogenic pulmonary edemas are more difficult to classify, in part because each shows features of both increased hydrostatic pressure and increased permeability. The prevailing theory about high-altitude pulmonary edema invokes hypoxia-induced pulmonary artery hypertension, but postulates that, in addition, the causative arterial vasoconstriction must be unevenly distributed within the lungs, which exposes some capillary networks to very high hydrostatic pressures and accompanying increased filtration. Elevated intravascular hydrostatic pressures in neurogenic pulmonary edema are triggered by intense sympathetic stimulation, which causes systemic and pulmonary vasoconstriction, a shift of blood into the lungs and stiffening of the left ventricular myocardium, all of which elevate pulmonary capillary hydrostatic filtration pressure. The increase in permeability, which has been observed in both high-altitude and neurogenic pulmonary edemas,[9] presumably follows what West et al. have called 'stress failure of pulmonary capillaries':[15] high transmural vascular pressure (>40 mmHg), even when applied in a transient pulse, disrupts endothelial and epithelial membranes and junctions, thereby causing leakage of protein-rich fluid.

DIAGNOSTIC DIFFERENCES

The clinical features of acute cardiogenic and noncardiogenic pulmonary edema overlap; most patients present with shortness of breath and are found to be tachypneic, hypoxic and in distress. Nevertheless, the setting in which each variety develops usually differs strikingly. Acute cardiogenic pulmonary edema typically occurs in patients with known heart disease; new-onset cardiogenic pulmonary edema in patients without such history is most often caused by acute myocardial infarction. Noncardiogenic pulmonary edema, on the other hand, usually presents as the acute respiratory distress syndrome, and arises as a consequence or complication of a coexisting, often obvious, clinical condition, which may be either pulmonary or systemic: common examples include pneumonia, multiple trauma and sepsis of intra-abdominal origin. The decrease in arterial partial oxygen pressure (P_{O_2}) that regularly occurs in interstitial pulmonary edema of either variety is caused by ventilation-perfusion mismatching; by contrast, the hypoxia of alveolar flooding is more severe and caused by right-to-left shunting of blood.

Pleural effusions

Pleural effusions are commonly found in patients with congestive heart failure and, although with lesser frequency and magnitude, in patients with noncardiogenic pulmonary edema; the causative mechanisms are similar but the time course often differs in the two conditions. The essential step is for fluid to accumulate in the interstitial spaces of the lungs and to raise the pressure in the subpleural interstitium—after which fluid spills across the relatively leaky visceral pleural membrane into the pleural spaces.[16] Subpleural interstitial pressures may not rise to the same level in noncardiogenic as in cardiogenic pulmonary edema, because the injury to the alveolar epithelium in the former favors early alveolar flooding, which protects against a large elevation in interstitial pressure. The formation of pleural effusions serves as an auxiliary safety factor, because it diminishes the amount of fluid available to fill alveolar spaces and worsen already present hypoxia: compared to fluid in the alveolar spaces, fluid in the pleural spaces has relatively little effect on lung function. The differences in protein concentration in the edema fluid that forms in cardiogenic pulmonary edema on the one hand and

Table Ways of differentiating cardiogenic from noncardiogenic pulmonary edema

Historical background and clinical findings
Chest X-ray features
Heart size
Width of vascular pedicle
Distribution of edema
Presence of pleural effusion
Peribronchial cuffing
Kerley B lines
Air bronchograms
Laboratory results
Electrocardiography
Brain natriuretic peptide
Echocardiography
Pulmonary artery wedge pressure

noncardiogenic pulmonary edema on the other are also evident in the protein levels found in the pleural fluids that accompany the two conditions (<0.7 and >0.7 of plasma concentration, respectively).

Other features

All the chest X-ray features listed in the Table are more commonly observed in cardiogenic than noncardiogenic pulmonary edema, with the exception of air bronchograms, but because all findings occur in both conditions, they have limited diagnostic utility. Laboratory examinations, beginning with electrocardiography and troponin levels, are useful if indicative of acute myocardial infarction. The level of brain natriuretic peptide (BNP) or of the aminoterminal fragment of its precursor proBNP, *N*-terminal proBNP, may be diagnostically helpful, especially if less than 100 pg/ml, which has a high negative predictive value for the presence of clinically significant heart failure; by contrast, many conditions beside heart failure cause elevated values.[17] Bedside transthoracic echocardiography is valuable in evaluating myocardial and valvular function in critically ill patients.

Ware and Matthay conclude that episodes of acute pulmonary edema in 'perhaps 10% of patients' are attributable to a mixture of cardiogenic and noncardiogenic causes:[8] for example, a patient with septic shock who has been volume overloaded or a patient with acute myocardial infarction who lost consciousness and aspirated. In such situations, or when the diagnosis remains in doubt, measurement of pulmonary artery occlusion (wedge) pressure should help settle the issue: pressure should be above 18 mmHg in cardiogenic pulmonary edema and at or below that level in noncardiogenic pulmonary edema.

CONCLUSION

Cardiogenic pulmonary edema results from a marked increase in pulmonary capillary hydrostatic pressure, whereas noncardiogenic pulmonary edema follows an increase in the permeability of the endothelium to fluid and protein. The two types are distinguished by the clinical setting in which each occurs, and also by different accompanying features, which are usually detectable by physical and laboratory examinations.

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RÉSUMÉ

Les poumons humains sains sont normalement le site d'une filtration des liquides et des solutions au travers de l'endothélium capillaire pulmonaire. A l'opposé d'autres organes, les filtrats au niveau du poumon sont confinés sur le plan anatomique à l'intérieur des espaces interstitiels voisins au travers desquels ils se déplacent en fonction du gradient de pression créé à partir du site de formation vers le site de résorption par les conduits lymphatiques pulmonaires. La quantité de liquide filtré et son contenu en protéines dépendent des différences de pression hydrostatique et osmotique protéique (colloïde) transvasculaire et du degré d'étanchéité de la barrière endothéliale en ce qui concerne l'eau et les protéines. Le drainage lymphatique peut augmenter de plusieurs fois, ce qui signifie que l'œdème pulmonaire, défini comme une augmentation du contenu d'eau extravasculaire au niveau des poumons, ne peut pas survenir sans que le taux de filtration des liquides dépasse le taux de résorption lymphatique. On connait deux types principaux d'œdème pulmonaire. Le premier, l'œdème pulmonaire cardiogénique (ou hydrostatique) provient comme le nom l'indique d'une pression capillaire pulmonaire élevée par suite d'une insuffisance du cœur gauche. Le deuxième, l'œdème pulmonaire non cardiogénique (lié à une augmentation de la perméabilité), provient de lésions des barrières endothéliales et habituellement épithéliales. En raison de ces différences fondamentales, chacun des deux survient dans des conditions cliniques distinctes, exige un traitement particulier et comporte un pronostic différent.

RESUMEN

En circunstancias normales, en los pulmones sanos en el hombre tiene lugar la filtración de fluidos y solutos a través del endotelio capilar pulmonar. A diferencia de otros órganos, el filtrado en los pulmones se encuentra confinado anatómicamente en los espacios intersticiales adyacentes, a través de los cuales se desplaza gracias a un gradiente de presión, desde su punto de formación hasta su punto de eliminación por los canales linfáticos pulmonares. La cantidad de fluido filtrado y su contenido proteínico depende de la diferencia transvascular de presión hidrostática y de presión osmótica (coloidea) y de la permeabilidad de la barrera endotelial al agua y las proteínas. El sistema de drenaje linfático tiene la capacidad de multiplicar varias veces su volumen, lo implica que el edema pulmonar definido como el incremento del contenido de agua del espacio extravascular del pulmón solo puede ocurrir cuando la tasa de filtración excede la tasa de eliminación por los linfáticos. Se conocen dos tipos principales de edema pulmonar. El primero, el edema pulmonar cardiógeno (o hidrostático), causado como su nombre lo indica por un aumento en la presión capilar pulmonar originado por una insuficiencia cardíaca izquierda. El segundo, el edema pulmonar de origen diferente al cardiógeno (por aumento de la permeabilidad), originado por una lesión de la barrera endotelial y con frecuencia de la barrera epitelial. Dadas sus diferencias básicas, cada tipo de edema se presenta en condiciones clínicas diferentes, exige un tratamiento específico e implica un pronóstico diferente.